AD-778 006

HUMAN USE OF WORLD KNOWLEDGE

Robert M. Balzer

University of Southern California

Prepared for:

Advanced Research Projects Agency

March 1974

AD 778 006

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2 GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
ISI/RR-73-7		

4. TITLE (and Subtitle)	5. TYPE OF REPORT & PERIOD COVERED
Human Use of World Knowledge	Research Report
	6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)	8. CONTRACT OR GRANT NUMBER(s)
Robert M. Balzer	DAHC15 72 C 0308

9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
USC Information Sciences Institute 4676 Admiralty Way Marina del Rey, California 90291	ARPA Order No. 2223/1

11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE
Advanced Research Projects Agency 1400 Wilson Blvd. Arlington, Virginia 22209	March 1974
	13. NUMBER OF PAGES
	25

14. MONITORING AGENCY NAME & ADDRESS(If different from Controlling Office)	15. SECURITY CLASS. (of this report)

	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution unlimited. Available from National Technical Information Service, Springfield, Virginia 22151

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Domain independent, model acquisition, natural language, nonprocedural languages, problem specification, world knowledge.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

(OVER)

DD FORM 1 JAN 73 14.` EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

1

ABSTRACT

Three experiments are presented to examine how humans use world knowledge in complex situations and to see if people can acquire new knowledge in a formal way (i.e., symbolic and linguistic rather than experience-based knowledge) without a strong semantic understanding of the area of discourse.

These experiments limit the interactions between the new area of discourse and the subject's existing body of world knowledge by translating each of the content words of the new area into a nonsense word, and presenting the subject with a mixture of the original English description and the substituted nonsense words.

The experiments utilized areas of discourse of different size and complexity, and with different experimental environments desired to elicit both the conclusions being drawn and the evidence upon which they were based.

These experiments indicate: that subjects are able to acquire new knowledge expressed in unfamiliar terms; that function words play a central role in this process; that some portion seems to be rule-driven and mechanizable; that world knowledge is extensively utilized to validate the local plausibility of interpretations; and that style is an important aspect of this process, enabling subjects to determine the important sections of a passage and how description flows from one sentence to the next.

Robert M. Balzer

Human Use of World Knowledge

UNIVERSITY OF SOUTHERN CALIFORNIA

VIEWS AND CONCLUSIONS CONTAINED IN THIS STUDY ARE THE AUTHOR'S AND SHOULD NOT BE INTERPRETED AS REPRESENTING THE OFFICIAL OPINION OR POLICY OF THE UNIVERSITY OF SOUTHERN CALIFORNIA OR ANY OTHER PERSON OR AGENCY CONNECTED WITH IT.

C O N T E N T S

ABSTRACT

Three experiments are presented to examine how humans use world knowledge in complex situations and to see if people can acquire new knowledge in a formal way (i.e., symbolic and linguistic rather than experience-based knowledge) without a strong semantic understanding of the area of discourse.

These experiments limit the interactions between the new area of discourse and the subject's existing body of world knowledge by translating each of the content words of the new area into a nonsense word, and presenting the subject with a mixture of the original English description and the substituted nonsense words.

The experiments utilized areas of discourse of different size and complexity, and with different experimental environments desired to elicit both the conclusions being drawn and the evidence upon which they were based.

These experiments indicate that subjects are able to acquire new knowledge expressed in unfamiliar terms; that function words play a critical role in this process; that some portion seems to be rule-driven and mechanizable; that world knowledge is extensively utilized to validate the local plausibility of interpretations; and that style is an important aspect of this process, enabling subjects to determine the important sections of a passage and how description flows from one sentence to the next.

Preceding page blank

INTRODUCTION

Human use of world knowledge is a concern of artificial intelligence both as an estimate of the amount of world knowledge required to solve particular problems and as a suggestion of techniques for utilizing such world knowledge. However, since this topic is so ill-defined, psychological experiments which deal at interesting levels of complexity have been very hard to define. Therefore, most knowledge of this area is based on our own intuitions.

While we are not psychologists, we would like to present three experiments which deal with complex real-world-type situations and which should shed some light on how humans use world knowledge in complex situations. All of these experiments are based on a common technique, Content Suppression, that, in the hands of professionals, should provide a tool for further investigation of the amount of world knowledge used by human subjects and the mechanisms by which they process such world knowledge.

We were drawn into a study of world knowledge by our investigations into automatic programming systems[1]. It is our view that one important capability of such a system is the ability to acquire knowledge about a new problem area and then to bring this knowledge to bear in following instructions while attaining goals specified by the user. It is our contention that only through such world knowledge of the domain can the system intelligently process the user's requests and move from essentially macro-based languages to context-dependent ones. This movement represents, we feel, the next major advance in programming systems.

WORLD KNOWLEDGE ACQUISITION

In our report[1], we demonstrated the power of world knowledge acquisition through a hypothesized worst case situation in which the user, while not being evasive, only answered the system's requests for information. From an initial statement by the user of his goal, the system had to discover the relationships between the objects of that world, construct a model of that world from such relationships, and then utilize this model in achieving the user's goal.

We include below this hypothetical dialogue along with the hypothetical reasoning that we would like such a system to employ.

Lines preceded by U: are input from the user; lines preceded by S: are responses from the system; and everything within square brackets ([]) is an explanation of how the system is processing the input and the inferences it is making. Thus, analysis will always follow the input or response being analyzed.

U: Let's build an Airline Reservation System.
   [Create a new model called 'Airline Reservation System'.]
S: OK. How?
U: We want to be able to tell how many seats are free on each
   flight.
   [There exist a set of entities called 'flights'. One of the
   attributes of flight is 'seat' and there are an unknown number
   of seats per flight. One of the values of some attributes of
   seat is 'free'. Goal of 'Airline Reservation System' is to
   keep track of free seats on each flight. Because free seats
   must be kept track of, there exists some operation or
   operations which changes either the number of seats per
   flight or the value of the unspecified attribute of seat to
   something other than 'free'.]
S: Besides being free what else can seats be?
   [Since system must keep track of free seats, it attempts
   to find out what other 'types' of seats there are.]
U: Reserved.
   [Seats can be either 'reserved' or 'free'.]
S: How many seats are on a flight?
   [Now that 'type' of seats are known, how many seats are
   there.]
U: It depends on the type of airplane.
   [There exists a set of entities called airplanes which
   have a type and this type determines the number of seats on
   a flight. Hence there is an association between an airplane
   and a flight.]
S: How are airplanes and flights related?
   [Ask user to state implied relationship.]
U: A flight is the movement of an airplane from a departure
   point to a destination.
   [A flight consists of an airplane, a departure point, and
   a destination. The action of a flight is to move its
   airplane from its departure point to its destination. A
   flight does not have seats as an attribute. An airplane
   has seats as an attribute.]
S: How does the type of airplane determine the number of seats?
   [Find out relationship between type of airplane and number
   of seats.]
U: Let's worry about that later.
   [Mark this relationship for processing later.]
S: OK, how do free seats become reserved?
   [Find out what operations exist to change 'type' of seat.]
U: A reservation for a seat on a flight changes a free seat to
   reserved, and a cancellation changes a reserved seat to free.
   [A reservation is an action which changes the 'type' of a
   seat from free to reserved. A cancellation is an action
   which changes the 'type' of a seat from reserved to free.

Assume that cancellation is also for a seat on a flight and that therefore reservation and cancellation are inverse operations. Assume that the changed seat is part of the airplane associated with the specified flight.]

S: Is the altered seat part of the airplane associated with the flight?
[Test this assumption.]

U: Yes, it is on the flight.
[Seats are 'on' not 'part of' airplanes.]

S: How do reservations occur?
[Are reservations an externally- or internally-controlled action and what are its prerequisites?]

U: Both reservations and cancellations are specified from a terminal.
[One or more terminals will be connected to the resulting system. Reservations and cancellations are externally-controlled actions initiated by some input from a terminal.]

S: What input initiates a reservation?
[What is form of reservation command?]

U: 'Reserve<flight> <date>'; similarly for cancel.
[(Note: angle brackets are used to indicate something which evolves to a specification of an object of the type named within the angle brackets.) A reserve or cancel command specifies the flight on which a seat is to be reserved or canceled and a date.]

S: What is the function of the specified date?
[What is the relationship between reservation, flight, and date?]

U: Flights occur periodically as specified in the airline schedule and date is used to specify a particular one.
[There exists an airline schedule which specifies when flights occur either with respect to some specified date or to some periodicity. To specify a particular flight, the flight specification must also be accompanied by a date.]

U: OK, let's test the system.
[Model is not complete. We can't simulate it yet.]

S: Wait a minute. First, how is the type of airplane on a flight determined?
[We need to know type of airplane for each flight, the airline schedule, and initial 'type' of seats on a flight.]

U: It is specified in the Airline Schedule which is in file Airline.Schedule.
[Airline Schedule specifies type of airplane on a flight. Airline Schedule is in file Airline.Schedule.]

S: Are seats initially free or reserved?

U: Free.
[Seats on a flight are initially free.]

S: OK, let's simulate the system.

   In condensed form, the model consists of the following information:

   1. Goal is to keep track of free seats on each flight.
   2. A flight is the movement of an airplane from a source point to a destination.
   3. The type of the airplane determines the number of seats on the flight.
   4. Seats are either free or reserved, and initially they are all free.
   5. Reservation and cancellation are actions, specified from a terminal, which change the status of one seat from free to reserved or reserved to free, respectively.
   6. The flight and type of airplane used on the flights are specified in an Airline Schedule.

Several people who were shown this dialogue were unconvinced about its feasibility. They felt it only worked because the system always asked the right questions and because it made the right inferences from the replies given. Both these activities, they felt, depended upon a very large, and unstated, body of world knowledge. Thus, implementation of such a system would be infeasible.

EXPERIMENT 1: SIMPLE CONTENT SUPPRESSION

In an effort to dispel this criticism, we were forced to devise an experiment that would support our contention that only very limited use of world knowledge was necessary to support such a dialogue. Such an experiment requires the ability to cut off, or limit, the interactions between the new area being explained to the system and the body of world knowledge that might be brought to bear on understanding such a new environment. We felt this could be most effectively done, through Content Suppression, by translating each of the content words of the new domain into a nonsense word and presenting the information as a mixture of normal English with the translated nonsense words appearing wherever one of the content words of the domain would have been used.

We ran this experiment with four subjects, each of whom was a programmer. We asked them to solve the problem with the same ground rules as the previous hypothetical dialogue: namely, they had to ask questions to gain information from a user who understood the domain. Part of one protocol from this experiment is given in Appendix I; the full protocol and others are available upon request from the author.

Each subject was able to solve the problem in about one half hour, although none was able to relate the solved problem to any real-world situation. The scenario generally followed the hypothetical discourse, above, which was generated prior to the experiment. All of the subjects experienced difficulty with the use of the word 'flight' to represent a set of flights, which had to be disambiguated with a date to specify a particular one. Some of the subjects also experienced difficulty in realizing that: seats were indistinguishable; the domain had no way of getting to a particular one; and if they wanted to do so, they had to construct an internal data structure themselves.

4

We feel that this limited experiment demonstrates that people can acquire new knowledge in a formal way (i.e., symbolic and linguistic rather than experience-based knowledge) without a strong semantic understanding of the domain.

However, this experiment dealt only with a very well-thought-out problem and contained just fourteen content words that had to be translated. We also wanted to investigate whether the same techniques were applicable to real descriptions of how to do something or the way something worked. We therefore ran two other experiments, both of which dealt with descriptions that were randomly selected from books, with the same basic philosophy of substituting nonsense words for the content words of the domain.

EXPERIMENT 2: COMPLEX CONTENT SUPPRESSION

The second experiment involved a single subject (the author) and was noninteractive, consisting only of the translated description taken from a book. This problem was much more complex than the first one, involving eighty-six translated content words. It and the subject's solution are presented below as a set of triple lines. In each set, the top line represents the original untranslated text of the problem, the middle line represents the text as given to the subject, and the bottom line represents the subject's solution to the problem. These sets are followed by the subject's written protocol which he used to solve the problem.

   (1) Problem 1:

   (2) When the chain attached to the lever of the flushing cistern is
               pottle sprocked   framper   lorching lank
               ---   connected   ---   ---   ---

   (3) pulled, the hollow iron bell-shaped unit rises and
        flumed   zif   lug rampled   lorks
        pulled   ---   ---   ---   ---

   (4) opens the passage to the flush pipe. As soon as water flows down
        rundles   trank   lorch mit   krumper lud glimp
        opens   ---   --- pipe   water flows down

   (5) this pipe, a vacuum is formed in the cavity of the bell and causes
          mit   luff   stiffled   grindle   dorf
         pipe   ---   formed   ---   ---

   (6) more water to flow from the cistern through the bell and down the
         krumper   lud   lank   dorf   glimp
         water   flow   tank   ---   down

(7) pipe. The cavity inside the bell thus acts as a siphon.
    mit   grindle grobble dorf   yams   zog
    pipe   ---   within   ---   acts   ---

(8) When a vacuum is formed at C (by initially applied suction),
        luff   stiffled   brobed leeplon
        ---   formed   ---   ---

(9) water is drawn through the siphon tube. Once the flow has been
    krump   flltz   zog   plutz   lud
  water   ---   ---   ---   flow

(10) started, it will continue. For the siphon to function, its outlet
    foped   nud   zog   orklon   frob
    started   continue   ---   function   ---

(11) must always be below the level of the water in the tank. When the
        gronk   tove   krumper   mung
        above or below level   water   container

(12) chain of the water closet has been briefly pulled and released, the
    pottle   krumper frotz   flumed   regritched
    ---   water   ---   pulled   released

(13) bell falls back into position over the inlet of the flush pipe,
    dorf zorchs bart   bletchlon   blutz   lorch mit
    --- moves   ---   position   mouth   --- pipe

(14) but the flow of water down the pipe continues - thanks to the siphon
        lud   krumper glimp mit   nuds   zog
        flow   water down   pipe continues   ---

(15) effect - until the cistern has been drained. As the water level
    lerp   lank   zonked   krumper tove
    ---   tank   emptied   water level

(16) in the cistern goes down, the float descends and opens the water
        lank   glimp   bllb   yads   rundles krumper
        tank   down   float   falls   opens   water

(17) supply valve, so that the cistern fills up again. When the float
    drortly cavem   lank tuboats   bllb
    --- valve   tank fills   float

(18) has risen to a certain level, the inflowing water is cut off by the
        rankle   tove   wipsening krumper rosehart
        risen   level   rising water shut

(19) valve. The capacity of the flushing cistern is usually 2 gallons.
    cavem   beglpt   lorching lank   panzers
    valve   capacity   ---   tank   gallons

(20) Fig. 3 (not shown) illustrates another type of cistern. When the rod is
        omps   arg lank   leffer
        shows   type tank   ---

(21) briefly pulled up and then released, the water here, too, continues
        flumed   regritched krumper   nuds
        pulled   released   water   continues

(22) to flow until the cistern is drained. The rod is provided with a
    lud   lank   zonked   leffer roppled
    flow   tank   emptied   ---   ---

(23) freely movable float which is prevented from floating to the surface
    grotly   metz   blib   whatsised   blibing   funk
    ---   ---   float   prevented   floating   surface

(24) of the water by two steps on the pull rod. When the rod is raised
          krumper   zaps   flum leffer   leffer   plated
          water   pins   pull   ---   ---   ---

(25) and the inlet of the flush pipe is opened, the closing pressure which
          blutz   lorch mit   rundled   fluding cropper
          mouth   --- pipe   opened   - --   ---

(26) Is developed by the water column in the full tank is reduced. The
      muffered   krumper frag   muna   regandrd
       ---   water left   container ---

(27) buoyancy of the float predominates and keeps the pipe inlet open.
    drode   blib   goths   lotsos   mit blutz rundle
    ---   float   ---   keeps   pipe mouth open

(28) Then the rod descends and the rubber valve disc is thrust against
        leffer yads   frerker cavem stremple ellis
        ---   falls   ---   valve   ---   held

(29) Its seat by the inflowing water.
      gnagy   wip_ening krumper
      limit   rising   water

(30) In some systems the flush pipe is connected to the water supply
          rops   lorch mit floppered   krumper drort
          models   ---.pipe   ---   water   ---

(31) through a lever-operated or a pushbutton operated
           blitzened   gipe   vuffled
           ---   ---   ---

(32) valve. In the former the flushing operation is
    cavem   stiffler   lorching vuffleion
    valve   former   ---   ---

(33) Initiated and terminated by hydraulic pressure equalization which
    glbed   roged   marg   cropper   cropion
    ---   ---   ---   ---   ---

(34) Is effected by the composite valve system. In the pushbutton
      lerped   zilla   cavem rop   gipe
      ---   ---   valve model   ---

(35) type, actuation of the pushbutton initiates the flow, which is
    arg   bisbey   gipe   lud
    type   ---   ---   flow

(36) subsequently likewise cut off by pressure equalization and spring
              osehart   cropper   gropion   donnering
              shut   ---   ---   ---

(37) action.
    yamion
    action

The following protocol was used by the subject of the above experiment to solve the problem. The numbers following each component of that protocol represent the line of the text (see above) from which the information was found that helped generate that component. The table of Attributes and Relations was used to structure this protocol.

ATTRIBUTES AND RELATIONS

x is an operation on y	(IO x y)
x is a relation between y and z	(x y z)
x is a part of y	(iPO x y)
x is an attribute value of y	(AVO x y)
x is nondiscrete	(nondiscrete x)
x is associated with y	(IA x y)
x is an attribute of y	(Atr x y)
x modifies y	(Mod x y)

```
(IO flum <pottle>)2 (sprock pottle framp)2
(of framp lank)2 (AVO lorch land)2
(AVO lorch wuffle)34 (AVO lorch mit)32
(AVO zif unit) (AVO luq unit)3
(AVO rample unit)3 (IO ork unit)3
(rundle unit trank mit)4 (AVO glimp lank)16
(nondiscrete krumper)6 (eq lud flow)6
(eq yam act)7 (encloses dorf krumper)6
(contained in krumper trnk)6 (eq tuboats (one of rises fills))17
(rundle blib krumper ?)16 (rundle ? blutz ?)26
(eq rosehart shut)18 (of tove krumper)11
(IO lud krumper)4 (AVO glimp krumper)4
(set mit)5 (IO stiffle luff)5
(of grindle dorf)5 (IO fop lud)9
(IO nuc lud)10 (IA glimp mit)6
(eq grobble within)7 (yam grindle zog)7
(IO flutz krumper)9 (of plutz zog)9
(through plutz krumper)9 (when (fop lud)(nud lud))10
(IO ork zog)10 (of frob zog)10
(type gronk position)11 (container mung krumper)11
(of frotz krumper)12 (of pottle frotz)12
(IO pottle gritch)12 (of blutz mit)13
(eq bletch position)13 (eq zorch move)13
(eq ork function)10 (eq tove (one of level temperature))18
(eq gronk (one of above below)11 (eq omp show)21
(eq arq type)21 (eq nud continue)10,14
(eq blutz mouth)13 (eq zork fill)15
(eq glimp down)16 (eq rosehart (one of closed shut))18
(eq rankle risen)18 (eq wipsen(one of rising entering))18
(eq bilb float)18 (eq cavem valve)18
(eq yad(one of falls descends))16 (eq rundle opens)16
(like leffer pottle)22,12 (eq whatsis(one of stop prevent))24
(of yars leffer)25 (eq funk(one of top surface))24
(eq ellis held)9 (eq fraq left)27
(eq rop model)32 (eq stiffle form)34
(type beglpt measure)19 (unit panzer beglpt)19
(eq lotso keep)29 (eq sprock (one of attach connect))2
(type flum move)3 (opposite flum gritch)12
(eq fop start)10 (type zog valve)5-7
```

8

This experiment was only partially successful. Rather than solving this problem by creating a formal model of the interactions between the components of the domain, the subject performed a type of cryptanalysis and attempted to decode the problem into terms that he understood. He thus brought to bear very large amounts of world knowledge in decoding particular passages of this text. As an example, consider the passage from lines 5 through 6 which was the key to decoding this problem: "and causes more krumper to lud from the lank through the dorf...". The subject noticed in this passage that krumper was not pluralized; hence, he drew the conclusion that krumper was a mass noun, that is, something considered as a group of things without consideration for the individual elements. Examples of such mass nouns are sugar or flour. The next part of the passage says to lud from someplace through something. Thus, lud is some type of a movement verb. From our knowledge of English syntax, English vocabulary, and how mass nouns move, we know that lud is probably either pour or flow. The subject was thus utilizing all the world knowledge at hand to find out some properties about the objects being discussed and then fitting those into the set of known possibilities for such properties.

Analysis of the protocol by the subject himself has, however, begun to yield a set of rules which we hope will begin to define the way such formal models are built up and knowledge is extracted from such passages.

EXPERIMENT 3: GROUP CONTENT SUPPRESSION

In an attempt to overcome the decoding process which occurred in the second experiment, and to make more accessible the reasoning processes which were being used by the subject, we devised a third experiment. This again was a noninteractive experiment in which the subject was presented with a description of how to do something or of the way something worked, taken from a book, after the content words had been translated. We made two significant changes in this experiment. First, the sentences were presented to the subject one at a time. A protocol was taken on each sentence so that the subject was forced to focus on that particular sentence and extract all the information he could from it. Second, instead of a single subject, we had a group of subjects sitting around

a table and conversing with one another to make explicit both the conclusions they were reaching and the evidence being extracted from the problem. The subjects were explicitly told not to attempt to decode the problem, but rather to build a model that represented the interactions between the objects being described.

The original and translated versions of the problem are given below and a protocol of the first few sentences appear in Appendix II.

(0) Sooner or later everyone runs across the problem of fastening
                                                    pottling

(1) something to a wall inside the house. Though the first impulse may
              sprock   lorch

(2) be simply to drive a nail into the wall, this seldom proves a
              lank   flum   sprock

(3) satisfactory solution. Since interior walls are usually hollow, the
                              zif   sprocks   lug

(4) nail merely breaks through into empty space - leaving you with
    flum   ramples   lork rundle

(5) little more than some cracked plaster and a useless hole for your
                              tranked miter   krump

(6) trouble.

(7) To provide a more satisfactory solution to this problem, there

(8) are many special wall fasteners that can be used. Regardless of
              sprock pottlers

(9) the size or weight of the fixture being hung, chances are there
    luff   stiffle   grindle   foped

(10) is a fastener available which will do the job. The load
        pottler   grobble

(11) that can he supported is limited only by the strength
              yamed   zoged   brob

(12) of the wall material itself.
        sprock leep

(13) For light-duty jobs, such as hanging small pictures and
        flitz   plutz   foping   nuds

(14) decorative plates, there are hangers available which can be
      ork   frobs   fopers

(15) cemented in place against the wall. Some of these come with
      gronked   sprock

(16) a separate liquid adhesive, while others are adhesive-
              mung   frotz   frotz

10

(17) backed. Since this type of device sticks to the surface only
        gritched   bart   bletchs   blutz

(18) it is limited by the strength of the surface coating which
        zoned   brob   blutz lerping

(19) is already in place on the wall.
                            sprock

We learned three things from this experiment. First, the subjects placed very
heavy emphasis on the use of function words and utilized them to ascribe a relationship
between unknown objects in the domain. Thus, awareness about the domain was largely
built up from knowledge about the function words. Such knowledge represents a fairly
well-defined and limited body of information, and should be amenable to incorporation in
a mechanized system.

Second, although the subjects were instructed not to decode the problem, as they
were attempting to use the function words to relate the objects in the domain they
constantly worked back to known real-world situations that were a possible explanation
of the given situation. That is, the subjects seem always to search through their
experience for an instance of a situation that could be described in terms of the
particular interpretation being placed on the sentence. Through such a mechanism, they
decided their interpretation of the relationship between translated words was plausible.
These instances did not remain consistent from sentence to sentence and so did not
appear to be important in understanding the situation, but were constantly being used to
test the local plausibility of the interpretation of the passage.

Third, subjects were able to pick up the writer's style and to use this to:
determine where to look for information; relate sentences to each other; and develop a
general flow of the explanation. All of this occurred, apparently, before much
understanding of the domain had been acquired by the subjects.

Finally, one very surprising thing happened. Two of the five subjects could
identify the problem domain after only a single sentence had been presented. The
sentence "Sooner or later everyone runs across the problem of pottling something ⌐ a
sprock inside the lorch." contains almost no content, yet it seemed to set the stage for
the subjects and gave them a good feeling of the type of problem to be discussed. It

11

demonstrated how incredibly quickly people are able to lock on to and utilize stage-setting information to establish context.

CONCLUSION

In conclusion, then, these experiments seem to indicate that

1. subjects are able to acquire knowledge about a domain described in unfamiliar terms;

2. the use of function words in such descriptions is very important to the understanding process;

3. some portion of such knowledge acquisition seems to be mechanizable through a set of rules;

4. subjects utilize world knowledge extensively to test local plausibility of interpretations;

5. style is an important aspect of a description, for it enables subjects to determine the important sections and how a description flows from one sentence to the next.

REFERENCES

1   Balzer, Robert M., _Automatic Programming_, USC/Information Sciences Institute, RR-73-1, (draft).

Below is the first part of the protocol of one subject in our experiment to test the feasibility of domain-independent problem acquisition and solution. The protocol is followed by the dictionary of domain-dependent words and the corresponding nonsense words.

> The goal of this experiment is for you to design an implementation of a model that I am going to describe to you. I am going to describe a goal and it is going to be a simple statement of what it is you are supposed to accomplish. Now, after that, it is expected that you are going to be the active element in the discourse, so that you will ask me for any information that you need to carry out the goal and I will give you that information. I am not going to spontaneously give you information. You have to ask for whatever you need. OK? What we have done is purposely express this model in terms of some nonsense words so that you cannot relate it to anything you know about. We are recording this so it would help if you do your thinking out loud. OK - the goal is to build a frobnication system and what we're supposed to do is to keep track of the number of gronked frobs on each tove.

Q. On each tove?
A. Tove - t o v e.
Q. OK - that's it. How do frobs get gronked?
A. There's an operation called frynation which changes the
    status of a frob which is not gronked to gronked.
Q. How are frobs created?
A. Frobs are neither created or destroyed - they are part of
    a frotz.
Q. OK - are many frotz part of a tove?
A. No. Associated with each tove there is a type of frotz.
Q. So each tove represents a frotz and a frotz is made up of
    many frobs. Why are frobs frynated? Does a frynation of
    a frob make it a gronked frob?
A. Right. That's part of the operation of this system.
Q. Is the number of toves static?
A. Yes, it's specified in the bletch.
Q. A bletch is...
A. A bletch is a table that is part of the input to the system.
    You can look up in the bletch how many toves there are.
Q. OK - so the bletch is the initialization, basically.
A. Yes.
Q. OK - I've bletched and now have a given number of toves
    which are all made up of frotz and those frotz contain
    frobs.
A. Each tove may have a different frotz.
Q. Right, certainly - and how are the frotz specified?
A. That's also part of the bletch.
Q. Are frotz all specified initially during the bletch to be
    ungronked frobs?
A. Each frob on a frotz is initially gronked.
Q. Is initially gronked...how do you ungronk a frob?
A. There's an operation called munqnation and a munqnation
    of a frob changes the status from gronked to munged.
Q. Is a munged frob the same as an ungronked frob?
A. Yes.
Q. Under what circumstances will munqnation occur in the
    frob?
A. Both munqnation and frynation are specified from one of
    a set of terminals.

Q. OK - do you want a constantly running number of the number
   of gronked frobs?
A. At any point I wish to be able to query and find out how
   many gronked frobs there are on a tove.
Q. On a particular tove?
A. Yes.
Q. How does one specify a tove?
A. A tove is specified by both a tove name and a bart.
Q. A bart is...
A. A bart is an atomic thing.
Q. A bart is a frob.
A. A bart is something that is used. A tove by itself specifies
   a set of toves, actually - a tove name by itself specifies a
   set of toves - to pick out a particular one you have to specify
   also a bart so a combination of a tove and a bart gives you a
   particular tove.
Q. OK. Is the tove in a bart in a bart a reasonable access
   path?
A. A tove and a bart and a bart?
Q. Namely, how many levels of tove are there - by what you
   just said there appear to be two levels of toves. There's
   a tove - you access by saying a tove in a bart.
A. I'm a computer user - I don't understand computer terms.
   I don't know what access means.
Q. OK - to get to a frob what maximum amounts of information
   are you willing to give me to get to this frob?
A. I don't understand the word 'information' either.
Q. A tove and a bart is a tove.
A. A tove name with a bart specifies a particular tove.
Q. ...and do you want to specify a frob which is part of that
   tove?
A. The bietch specifies the type of frotz associated with the
   tove.
Q. Frotz...
A. And the bietch also contains the number of frobs for each
   type of frotz.
Q. Can we go over what's a frotz again? A frotz is a
   collection of frobs?
A. Yes - a frotz is associated with the tove and each tove has
   associated with it a type of frotz, and that's the same for
   all toves without specifying a bart. In other words, if
   you just give a tove name that specifies a set of toves
   which are identified by their barts but all of those toves
   have the same frotz. To completely specify a tove you need
   both the tove name and a bart, but all the things with the
   same tove name independent of the bart have the same frotz.
Q. All the things with the same tove name have the same type
   of frotz.
A. Yes.
Q. Independent of what?
A. Bart.
Q. A tove name followed by a bart leads to a tove.
A. Right.
Q. And that tove - let's talk about that specific tove - tove
   name followed by the bart - that tove is made up of a frotz.
A. Right.
Q. And that frotz is made up by several different frobs.
A. A number of frobs.
Q. Number - specified during the bietch?
A. Right.
Q. Now is a tove name followed by a bart followed by something
   specification of a particular frob?
A. No - all we know about frobs is the number of them on

each frotz.

Q. OK - if I wanted to frynate a frob the way I name
that frob is by a tove name followed by a bart.

A. Right.

Q. ...followed by what?

A. Followed by nothing. A frynation just says do it to one
of the frobs on that particular tove-bart combination.

Q. And I assume mungnation is the same phenomena in the
opposite direction.

A. Right.

Q. Why are you making a distinction about different types
of frotz? For what?

A. Each different type of frotz has a different number of
frobs.

Q. So one type of frotz has always a specified number of frobs.

A. Right. And that number is given in the bletch.

Q. Is the bart also a tove name?

A. No - the bart is used to disambiguate a tove name.

Q. In what sense?

A. A tove name by itself gives a set of things which have that
tove name. Each of those has a different bart and so by
specifying both the tove name and bart you get a particular
one.

Q. So the tove name is really a name of a type of the frotz.

A. No. Things with different tove names may have the same
frotz - they may have different ones - but everything with
the same tove name has the same frotz.

Q. Everything with the same tove name has the same type of
frotz.

A. Right.

Q. ...so any tove name followed by a specific tove name
followed by any bart will lead me to a frotz with the same
number of frobs on it.

A. Yes.

DOMAIN-DEPENDENT DICTIONARY

Fropnication System	Airline Reservation System
Frobs	Seats
Gronked	Free
Tove	Flight
Munged	Reserved
Frotz	Airplane
Gritch	Departure point
Zorch	Destination point
Mungnation	Reservation
Frynation	Cancellation
Mung	Reserve
Fry	Cancel
Bart	Date
Bletch	Airline schedule

Sooner or later everyone runs across the problem of pottling something
to a sprock inside the lorch.

: There is a great deal of context in that...
: Well, let's see. Suppose we know that lorches are different
  from sprocks because...
: ...because sprock is inside the lorch.
: Well, it could stick out...it could be an appendage to something
  that is tightly locked or pottled and like sticks out. I'm
  getting visions of things. It sure is wild.
: Well, I don't know if this is a valid thing to say but since
  everybody runs across the problem it can't be too highly
  mechanical a problem.
: A lorch could be some kind of a container or it also could be
  some kind of mechanism of which a sprock is a part.

Even if the thing was a mechanism isn't that a kind of container?

: Well, I was thinking of something inside like an automobile
  engine. I don't consider an automobile engine a container but
  you could do something to a something inside the engine.

The engine is a container.
That's not its primary use...

: All right...

But it seems to me that the word 'inside' only means container.

: OK. The word 'the' really strikes me as funny...

How's that?

: As inside 'the' lorch. The first sentence says this is really
  the context. This is a sentence out of the middle of a logical
  paragraph -- it wasn't the first thing that was ever said in the
  book.
: Although a smart robot mechanism might take this sentence to
  mean 'the lorch' which means that every person or every family
  or every organization of some type has a lorch.
: Within the law. Inside the law.
: Well, customarily, like you might say...do you talk about doing
  something to the car and the context there is that customarily
  every family has 'the' car or several 'the' cars.
: Or every once in a while you get stuck with the job of vacuuming
  around the house.
: You have to strain to think that 'the' is really part of the
  introductory sentence.
: Well, pottling seems to be fitting. If you pottle something
  to a something. There is a contact. It means making contact
  with a community.
: But pottling is also probably not a specific. A very task-
  specific kind of word (verb).
: ...because apparently there are many things that can be pottled
  to sprocks.
: That's right...the problem is when it's inside the lorch.
: I'd like to know whether a sprock is a part of a lorch or a
  sprock is a thing that's inside a lorch.
: ...whether a lorch is a container in which you do this pottling
  or whether you are actually pottling the sprock.

: ...every lorch is sprocked or has some sprocks.

I think it's best at this point to just recognize that it's something
we want more information about and see if the information comes in
the following text.

: ...it says 'a sprock'...there are probably several sprocks...
: ...there are probably inside and outside sprocks...
: ...that could be...it's a possibility...
: Well, what's the problem. Is the problem pottling or is the
  problem because it's inside?
: I think the inside is ambiguous.
: In what way?
: In the fact that we brought out -- that the sprock could be
  attached to the inside of the lorch and that you have to pottle
  something onto it, or that the lorch is a container in which
  you do the pottling...
: Are there any other alternatives?
: Let me see...
: A sprock seems to be an object. It could be a human, but I doubt
  it.
: We ought to number these sentences...
: Let's call this one 1.
: Yeah, I think we should number the sentences so we can refer
  back. Let me summarize my knowledge to this point: lorches
  are either contained or have as constituents some sprocks.
: That's much better than mine -- sprocks -- less than or equal to
  lorch; lorch -- container/mechanism; pottle -- contact or
  communication. I have inside and outside sprocks.
: Also, probably many things can be pottled.
: If we've already guessed it we have to keep quiet.
: If you already guessed it?
: I'm ready for another sentence.

Though the first impulse may be simply to lank a flum into the
sprock, this seldom proves a satisfactory solution.

: I think we have somewhat of a definition of pottling. To
  pottle -- to lank a flum -- seems to be one of the ways to
  pottle.
: No -- to lank a flum into is a way to pottle to.
: That's right. I guess if you lank the flum into the sprock that
  would be the same as pottling. That would define pottling
  something to the sprock.
: It's an instance. That's right. But evidently there are more.
: Is the flum something in the previous sentence.
: I think so...
: It may not be. I mean it may...
: Maybe this is something you have to do before you can pottle
  something on it you have to clear the sprock.
: Right. So a flum is just an attachment that will enable
  something to be pottled.
: ...pottles onto it.
: On the other hand a flum might be for you to pottle it.
: Or it might be that. And the lank would be actually an
  instance of pottling.
: On the other hand, if the flum were a thing you were pottling
  to the sprock then they would have probably said that you pottle
  a flum to a sprock, not pottle something.
: Maybe pottling a flum is incorrect usage of flum. Maybe you
  would never say pottling from the end of the Penn Central.
: Lanking sounds not too good -- lanking sounds like it just
  talks of it. I would say lanking is like tossing. Lanking

is not a thorough job. Or else a flum sounded very good when
you do it.
: Well, maybe lanking a flum is a good way of doing some things
but it's not as good as pottling to a sprock. It might even be
a good way of pottling to something else.
: It could be that it lengthened a flum that isn't very good.
: Or maybe lengthening is fine if it's the flum...
: There are lots of instances where one method of attachment
is good for one thing but isn't good enough for another
thing. Does it involve some kind of linking of something.
: Either linking or...
: ...including...
: Well whatever it is lanking a flum... or a flum doesn't do it.
I'm not sure whether it's the flum or the lanking -- the flum
or the lank.
: You can do something else to a flum.
: Or just lanking it once you are inside the sprock or into
the sprock...somewhere in that combination is... I would bet
that it's because it's inside that there's a problem.
: Are you doing all this inside the lorch.
: ...maybe you can lank a flum...
: Well, there's still, I guess, one...almost four ambiguous
possibilities whether you can...

I haven't counted, but it sounds to me like you're talking
about many more than that.

: Well, the main situation is that either to lank could be -- well,
not counting all the possibilities -- the simple possibility
that lanking is what causes the problem or that flum is the
problem -- or that you can't lank a flum...
: Or that the problem is that you are undecided...
: ...I'm sure you can lank a flum because you would try that but
if you can't do it into the sprock or that the whole thing is
done in the context of inside the lorch.
: This seems to imply that you can actually lank the flum into the
sprock under these conditions.
: Yes, that's right...
: ...but if you do it won't work -- it won't pottle very well.
: It might accomplish the problem but later it could fall apart...
: ...something will happen at night...
: Well, I'm ready for the next sentence...